Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

A99.9
F764U
C2

United States
Department
of Agriculture

Forest Service

**Intermountain
Research Station**

Research Paper
INT-454

June 1992

Cliff Lake Bench Research Natural Area: Problems Encountered in Monitoring Vegetation Change on Mountain Grasslands

Walter F. Mueggler

THE AUTHOR

WALTER F. MUEGGLER, now retired, was principal plant ecologist and project leader of the Intermountain Research Station's Aspen Ecology and Management research work unit in Logan, UT. At the time this work was begun, he was project leader of the Station's Mountain Grasslands research work unit in Bozeman, MT. He holds degrees in forestry from the University of Idaho and ecology from the University of Wisconsin, and a Ph.D. degree in plant ecology from Duke University.

RESEARCH SUMMARY

Vegetation on mountain grasslands in the Cliff Lake Bench Research Natural Area in southwestern Montana was sampled in 1969 and again in 1988 to assess possible change over a 20-year period on mountain grasslands free from livestock grazing. The sample years differed significantly in production and frequency of individual species, as well as in species composition of the vegetation. However, these differences are attributed primarily to short-term peculiarities of the two sample years rather than to long-term vegetation change. The data serve as an example of problems likely to be encountered in attempting to determine alterations in vegetation brought about by climatic change. Sampling adjustments are suggested to reduce the effects of some of these problems.

Intermountain Research Station
324 25th Street
Ogden, UT 84401

Cliff Lake Bench Research Natural Area: Problems Encountered in Monitoring Vegetation Change on Mountain Grasslands

Walter F. Mueggler

INTRODUCTION

Scientists and the general public are becoming increasingly concerned that the world is either on the threshold of, or worse yet, in the throes of global climatic change brought about by human activities. The result of such change on regional ecosystems is uncertain and can only be determined by careful monitoring. Knowledge of the magnitude and direction of changes in various ecosystems could help us understand the need to modify those human activities threatening our environment.

Monitoring climate-controlled changes in natural vegetation requires that the effects of other perturbations such as logging, livestock grazing, and fire be eliminated or controlled so the effects of climate change are not obscured. Research Natural Areas set aside by the Forest Service, U.S. Department of Agriculture, are obvious candidates for monitoring the effects of climatic change on a wide variety of natural vegetation types. However, monitoring and interpreting the effects of climatic change can be difficult even under ideal conditions where major extraneous disturbances can be controlled over long periods of time.

The purpose of this paper is twofold: (1) to document the composition and production of mountain grassland vegetation on a research natural area in southwestern Montana, and (2) to describe the problems encountered in attempting to interpret reasons for the difference in vegetation composition observed over a 20-year period. This experience is analogous to some of the problems that are likely to be encountered in attempting to assess alterations in vegetation brought about by climatic change.

THE CLIFF LAKE BENCH RESEARCH NATURAL AREA

Cliff Lake Bench is in the Beaverhead National Forest in southwestern Montana about 25 air miles west of Yellowstone National Park. The bench sits directly west of and about 500 feet above Cliff Lake. A 2,300-acre portion of the bench was set aside as a research natural area in 1951. Before then, the area received only sporadic light grazing, primarily by sheep, but occasionally by cattle. Grazing was light because the nearest permanent water was 2½ to 3 miles away at Wade Lake. After water was developed on the bench adjacent to the natural area, fencing effectively eliminated grazing by domestic livestock, except for occasional trespass when the fence needed repair. Deer, elk, and moose frequent the natural area during the summer.

The natural area is on gently undulating land at an elevation ranging from 6,800 to 7,400 feet. The soils are primarily fine sandy loams, fairly deep and highly porous. Estimated annual precipitation ranges between 20 and 30 inches and is fairly evenly distributed throughout the year, with about half falling as snow between November and March.

The vegetation on the natural area and adjacent portions of the bench consists of a coarse mosaic of natural grasslands/shrublands and forest types. About 40 percent of the natural area is open mountain grasslands and sagebrush-grass steppe, representative of the relatively undisturbed moderate- to high-elevation mesic grasslands in western Montana; about 45 percent is in lodgepole pine forest; the remainder is occupied by either Douglas-fir forests or clones of quaking aspen. Boundaries are sharp between the open grasslands/shrublands and the forest types; aspen clones frequent the interface.

The grasslands/shrublands occur in three distinct geographic units, facilitating identification and sampling. A 225-acre grassland (referred to as the North Grassland) in the northern portion of the natural area is classified within the *Festuca idahoensis/Agropyron caninum* habitat type, *Geranium viscosissimum* phase (Mueggler and Stewart 1980). A 350-acre sagebrush-grass steppe (South Grassland) in the southwestern portion of the natural area has been classified within the *Artemisia tridentata/Festuca idahoensis* habitat type, *Geranium viscosissimum* phase. And a 30-acre pocket of grassland (East Pocket) surrounded by forest on the southeast side of the natural area is classified the same as the North Grassland, although it has minor species differences.

SAMPLING METHODS

Only monitoring of the grasslands and shrublands is described in this report. The intent in 1969 was to base monitoring on possible changes in vegetation composition over time as determined from dry-weight production of individual species. A series of permanent plots was established on each of the major grasslands/shrublands areas to reduce the variability encountered in using random plot placement at each sampling time.

Each of the three areas was sampled with three macroclusters of plots. Macrocluster locations were widely distributed and subjectively selected for vegetation uniformity and for representation of the overall area. Each macrocluster consisted of 4 subclusters of plots systematically distributed within a macrocluster. Four individual sample plots, each 7 by 7 dm (0.49 m^2), were systematically distributed within a subcluster. The center point of each macrocluster and each sub-cluster were permanently marked, as was the location of each small sample plot. This distribution resulted in 16 plots per macrocluster and 48 plots for each grasslands/shrublands area.

These plots were sampled in early August of 1969 and again in 1988. Early August was selected as the period when maximum herbaceous growth would have occurred; the remoteness of the natural area precluded close tracking of plant development. Following a period of training, I estimated the weight of individual species on each sample plot. Periodically, a similar plot that was not part of the permanent plot series was estimated before being clipped by species. This provided a running accuracy check; estimates could subsequently be adjusted to reduce possible bias formed during the weight estimate inventory. Clippings from the check plots were returned to the laboratory for the determination of percent dry matter by species, determinations later used to adjust all weight estimates to a dry weight base. In addition, the amount of ground covered by vegetation basal area, cryptogams, litter, rock, and bare soil was estimated on each plot. The 48 production plots on each area were also used to compare differences in species frequencies between 1969 and 1988.

In 1988, I established a separate series of nested-frequency plots to supplement data from the weight estimate plots. I became concerned that species composition based on production alone was too subject to the yearly caprice of weather to be a reliable indicator of long-term change. Changes in species frequency appeared to promise a better method of evaluating long-term change in species abundance, yet would be comparatively simple and rapid. Frequency is not affected nearly as much by yearly weather variations as production. However, frequency is not an "absolute" measure such as production and density, and it is dependent on the size and shape of the sample plots. Repeat measurements based on plots of the same size and shape, however, should show whether a species is increasing or decreasing.

The size of a sample plot is critical in obtaining meaningful frequency data. Desirable plot size is a function of species abundance. A plot size yielding values of 100 percent frequency for a species, or 0 percent at the opposite extreme, would have limited value in detecting change in species abundance. Since the abundance of different species can differ greatly on a given area, the most desirable approach is to provide different sized plots to accommodate species with widely different abundance. This was accomplished by using nested plots of sizes believed suitable for most of the species on these grasslands (Hironaka 1985).

Three permanent frequency macroplots were established at the same locations as the production macroclusters on the North Grassland and South Grassland; limited time did not permit such sampling of the East Pocket. The macroplots are 20 by 20 m, with five randomly selected and permanently marked transects extending across the plot perpendicular to the south side. Ten nested frequency plots were placed at regular intervals along each of the transects, for a total of 50 plots per macroplot, or 150 plots per area.

Each nested frequency plot consisted of a basic 50 by 50-cm microplot subdivided into a 50 by 25 cm plot, a 25 by 25-cm plot, and a 5 by 5-cm plot. Rooted frequency of occurrence was measured on each plot size to obtain meaningful data on species with widely differing abundance. This nested frequency sampling scheme is similar to that used by the Forest Service's Northern Region and described in the 1987 version of the Region's Ecosystem Classification Handbook (Keane and others 1990).

The statistical significance of production differences between 1969 and 1988 was based upon a paired-plot t-test (df = 11) using subcluster sums of four plots as the sample unit, for a total of 12 sample units on each area. Significance of percent composition differences based on air-dry production was determined by paired-plot t-test (df = 2) using macrocluster sums as the sample unit, for a total of three sample units per area. Significance of frequency differences between years was determined by a Chi-square test using actual presence/absence counts.

COMPARISON OF 1969 AND 1988 DATA

Information on both production and frequency of individual plant species is useful in determining the direction and amount of vegetation change over time. Such data have particular relevance when expressed in terms of changes in species dominating the plant community. Interpreting the reasons for observed changes requires understanding differences in environmental factors possibly influencing the vegetation at the different times of measurement. Weather differences can have a major, though temporary, influence on plant data, as can the effects of cyclic animal populations.

Vegetation Production

The changes in vegetation between 1969 and 1988 differed somewhat between the three grasslands, primarily in the amount of change. Total air-dry production was less in 1988 than in 1969 on all of the areas, significantly so on two of the three areas (table 1). Whereas total production in the dry year of 1988 was 89 percent of 1969 production on the North Grassland, 1988 production was just 72 and 52 percent, respectively, of 1969 production on the South Grassland and East Pocket. Total forb production was also significantly less on the South Grassland and East Pocket in 1988 than 1969. Only the South Grassland had significantly less production of total grasses. Forbs appeared to suffer somewhat more than the grasses from the adverse conditions in 1988.

The only perennial species with significant reductions across all three grasslands were: *Lupinus argenteus, Perideridia gairdneri,* and *Achillea millefolium*. A number of other species produced significantly less in 1988 than in 1969 on some areas, but not on others. Most of the remaining species were less productive in 1988, but not significantly so. The exceptions were significant increases from 1969 to 1988 in *Potentilla gracilis* and *Poa interior* on the North Grassland and *Helianthella uniflora* on the South Grassland. The annual forbs, *Polygonum douglasii* and *Collomia linearis*, produced considerably less in 1988 than in 1969.

Of greater importance is whether these data demonstrate real changes in perennial species composition over the 20-year period. In general, the dominant species in 1969 remained dominant in 1988, but with a slight shift in order (table 2). The grasses continued to comprise about 40 percent of the total vegetation. The biggest shift was a greater proportion (not significant) of grasses in 1988 on the East Pocket grassland, with a corresponding decrease in forbs. *Festuca idahoensis* and *Bromus marginatus* remained the two most abundant grasses on the North Grassland and East Pocket; *F. idahoensis* and *Stipa occidentalis* remained the most abundant on the South Grassland. The most profound composition change among dominant perennial forbs was greater dominance of *P. gracilis* on the North Grassland, and *H. uniflora* on the South Grassland. *Geranium viscosissimum* remained one of the dominant forbs, although its proportions changed on the different areas. The most conspicuous difference among forbs of secondary dominance was the decrease in proportion of *A. millifolium, P. gairdneri* and *L. argenteus*.

The only shrub monitored was *A. tridentata* on the South Grassland. Its production in 1988 was about half of that in 1969 (table 1), yet its proportion of total vegetation production changed very little (table 2).

Species Frequency

Comparison of a species' frequency of occurrence on the 0.49-m^2 production plots is another measure of long-term vegetation change. Frequency may be an especially important monitoring device for a species that is not a substantial contributor to total vegetation production. The frequencies of the following secondary perennial forbs were significantly less on all three grassland areas in 1988 than in 1969: *Agoseris glauca, Campanula rotundifolia, L. argenteus,* and *P. gairdneri* (table 3). Frequencies of other secondary forbs also decreased significantly, but not consistently, across all grasslands. *Potentilla gracilis*, considered a major forb, had significantly greater frequency on both the North Grassland and East Pocket in 1988 than in 1969. The major annuals, *C. linearis* and *P. douglasii*, were less frequent on all areas in 1988.

Grasses significantly less frequent in 1988 than in 1969 were *Bromus anomalus* on both the South Grassland and East Pocket, *Melica spectabilis* on the North Grassland and East Pocket, and *Calamagrostis rubescens* and *F. idahoensis* on the East Pocket. Both *Koeleria cristata* and *Poa ampla* had significantly greater frequencies on the East Pocket in 1988.

The two grasses with the greatest frequency remained the same on all areas except the East Pocket, where the predominance of one species changed (table 3). Interestingly, the two dominant grasses on each area as measured by production were also those with the greatest frequencies, with the exception of East Pocket grasses in 1988. The two forbs with the greatest frequencies in 1969 on the North Grassland and East Pocket still had, or shared, the greatest frequency in 1988, but rankings changed on the South Grassland. On both the North Grassland and East Pocket, the two dominant

Table 1—Ground cover and vegetation production on three grassland sites on the Cliff Lake Bench Research Natural Area in 1969 and 1988

	North Grassland		South Grassland		East Pocket	
	1969	1988	1969	1988	1969	1988
Ground Cover (percent)						
Plant canopy	71.8	72.8	77.3	79.3	74.2	76.8
Lichen and moss	0	0	0	.6	0	0
Litter	18.0 ** [1]	24.2	18.4	17.3	21.0 *	17.3
Rock	.2	.1	0 *	.3	0 **	.3
Bare soil	10.0 **	2.9	4.3	2.5	4.8	5.6
Production (dry lb/acre)						
Grasses						
Agropyron spicatum	0	0	11.4 *	1.0	0	0
Agropyron subsecundum	45.0	48.5	86.0 **	26.3	58.9 *	34.4
Bromus anomalus	22.6	20.3	47.4 **	9.3	19.8 *	6.7
Bromus carinatus	280.8 *	158.0	57.4	29.9	103.1	69.8
Calamagrostis rubescens	25.0	30.6	0	0	35.1 **	0
Danthonia intermedia	3.9	8.6	30.3	32.0	21.6	25.3
Deschampsia cespitosa	1.1	0	0	0	1.8	0
Festuca idahoensis	177.2	173.4	261.2 **	142.1	133.7 *	97.5
Koeleria cristata	7.6 *	24.4	7.2	1.7	.8 *	11.1
Melica spectabiolis	11.4 *	1.9	0	.2	10.8 **	1.0
Poa ampla	4.1	7.6	15.0	18.4	1.0 *	16.2
Poa interior	21.4 *	90.3	0	4.2	3.8	11.6
Poa sp.	0	0	3.8	1.1	.7	.5
Stipa occidentalis	16.7	15.1	76.9	77.4	38.0	39.9
Stipa richardsoni	0	0	8.3	1.4	39.8 *	97.0
Total grasses	616.8	578.7	604.9 **	345.0	468.9	411.0
Sedges						
Carex douglasii	0	0	4.2	2.2	0	0
Carex filifolia	0	0	0	2.2	0	0
Carex geyeri	.8	0	0	0	26.0	11.2
Carex hoodii	0	0	3.1	1.2	21.5	0
Carex petasata	2.7	.5	16.3	9.1	10.2 *	33.9
Carex raynoldsii	11.4 *	13.6	1.0	.2	0	0
Carex sp.	.6 *	0	.2	4.3	1.0	0
Total sedges	15.5	14.1	24.8	19.2	58.7	45.1
Forbs						
Achillea millefolium	48.5 **	10.2	40.0 **	6.1	70.6 **	10.2
Agoseris glauca	5.1 **	0	12.3 *	.3	2.7 *	0
Antennaria anaphaloides	0	0	.9	.9	0	.5
Antennaria rosea	.6	.2	1.0	2.0	4.0	.5
Arabis spp.	2.4	0	3.1	0	.3	0
Arenaria congesta	4.6 *	1.4	25.2 **	1.8	13.7 *	1.4
Aster campestris	11.8	5.9	27.0	4.7	14.2	15.7
Aster integrifolius	19.0	24.1	32.3	26.8	56.4	33.1
Astragalus miser	0	0	2.8	0	.6	0
Balsamorhiza sagittata	0	0	12.7	8.9	1.9	0
Besseya wyomingensis	0	0	.2	0	0	0
Campanula rotundifolia	13.8 *	0	13.2 *	0	6.9 **	0
Cerastium beeringianum	2.4	2.1	.2 *	.5	0	0
Cirsium vulgare	0	0	1.9	17.1	.2	0
Clematis hirsutissima	6.6	9.6	10.8 *	.5	3.4	3.7
Collomia linearis	63.9	17.1	46.5	.3	20.9 **	2.0
Epilobium angustifolium	0	0	0	0	4.7	4.9
Erigeron speciosus	1.3	1.2	0	0	2.0	1.2
Erigeron subtrinervis	29.1 *	13.9	7.9 *	0	23.0	15.5
Eriogonum umbellatum	23.9	27.1	71.4 *	35.3	48.8 *	12.5
Fragaria virginiana	0	0	0	0	34.4	55.4
Galium boreale	0	0	0	0	2.8	0
Geranium viscosissimum	125.2 *	161.6	93.6 **	32.0	109.1	93.0
Geum triflorum	29.0 *	67.9	85.6	82.7	33.9	28.2
Helianthella uniflora	2.7	7.8	42.8 *	66.0	0	0
Hieracium sp.	0	0	0	0	6.7 *	1.3

(con.)

Table 1—(Con.)

	North Grassland		South Grassland		East Pocket	
	1969	1988	1969	1988	1969	1988
Linum perenne	0	0	3.8	1.6	7.5	10.3
Lupinus argenteus	19.2 **	0	20.0 *	0	29.8 **	8.2
Perideridia gairdneri	49.2 **	2.4	37.6 *	0	59.7 **	5.5
Phlox multiflora	0	0	6.9 +	12.5	0	0
Polygonum douglasii	214.7 **	6.0	5.1	.3	66.3 *	11.4
Potentilla arguta	40.0 *	67.8	58.3 **	19.6	38.4	24.8
Potentilla gracilis	89.0 **	256.5	43.5	26.7	162.4	173.0
Senecio integerrimus	0	.7	4.0	0	5.2	8.5
Silene oregana	2.4	0	2.0	0	3.2 *	0
Smilacina stellata	0	0	0	0	.8	2.4
Total forbs	804.4	686.0	712.6 **	346.6	835.1 **	523.2
Shrubs						
Artemisia tridentata	0	0	301.2	152.5	0	0
Total Vegetation	1,436.7	1,278.8	1,643.5 **	861.9	1,362.7 **	979.3

[1]Significance of production differences between years: + = >0.90; * = >0.95; ** = >0.99.

Table 2—Plant species percent composition[1] based upon vegetation production (air dry) on three grassland sites on the Cliff Lake Bench Natural Area

	North Grassland		South Grassland		East Pocket	
	1969	1988	1969	1988	1969	1988
	Percent					
Grasses						
Agropyron spicatum	0	0	0.7	0.1	0	0
Agropyron subsecundum	3.1	3.8	5.2	3.1	4.3	3.5
Bromus anomalus	1.6	1.6	2.9 +[2]	1.1	1.5	.7
Bromus carinatus	19.5	12.4	3.5	3.5	7.6	7.1
Calamagrostis rubescens	1.7	2.4	0	0	2.6 *	0
Danthonia intermedia	.3	.7	1.8	3.7	1.6 +	2.6
Deschampsia cespitosa	.1	0	0	0	.1	0
Festuca idahoensis	12.3	13.6	15.9	16.5	9.8	10.0
Koeleria cristata	.5	1.9	.4	.2	.1 +	1.1
Melica spectabilis	.8	.1	0	.1	.8	.1
Poa ampla	.3 +	.6	.9	2.1	.1 +	1.7
Poa interior	1.5	7.1	0	.5	.3	1.2
Poa sp.	0	0	.2	.1	.1	.1
Stipa occidentalis	1.2	1.2	4.7 *	9.0	2.8	4.1
Stipa richardsoni	0	0	.5	.2	2.9	9.9
Total grasses	42.9	45.3	36.8	40.0	34.4	42.0
Sedges						
Carex douglasii	0	0	.3	.3	0	0
Carex filifolia	0	0	0	.3	0	0
Carex geyeri	.1	0	0	0	1.9	1.1
Carex hoodii	0	0	.2	.1	1.6	0
Carex petasata	.2	.1	1.0	1.1	.7	3.5
Carex raynoldsii	.8	1.1	.1	.1	0	0
Carex sp.	.1 +	0	.1	.5	.1	0
Total sedges	1.1	1.1	1.5	2.2	4.3	4.6
Forbs						
Achillea millefolium	3.4 +	.8	2.4 +	.7	5.2 *	1.0
Agoseris glauca	.4	0	.7	.1	.2 +	0
Antennaria anaphaloides	0	0	.1	.1	0	.1
Antennaria rosea	.1	.1	.1	.2	.3	.1
Arabis spp.	.2	0	.2	0	.1	0
Arenaria congesta	.3	.1	1.5 *	.2	1.0 *	.1
Aster campestris	.8	.5	1.6	.5	1.0	1.6

(con.)

Table 2—(Con.)

	North Grassland		South Grassland		East Pocket	
	1969	1988	1969	1988	1969	1988
	Percent					
Aster integrifolius	1.3	1.9	2.0	3.1	4.1	3.4
Astragalus miser	0	0	.2	0	.1	0
Balsamorhiza sagittata	0	0	.8	1.0	.1	0
Besseya wyomingensis	0	0	.1	0	0	0
Campanula rotundifolia	1.0	0	.8 +	0	.5	0
Cerastium beeringranum	.2	.2	.1	.1	0	0
Cirsium vulgare	0	0	.1	2.0	.1	0
Clematis hirsutissima	.5	.8	.7	.1	.2	.4
Collomia linearis	4.4	1.3	2.8	.1	1.5 +	.2
Epilobium angustifolium	0	0	0	0	.3	.5
Erigeron speciosus	.1	.1	0	0	.1	.1
Erigeron subtrinervis	2.0	1.1	.5	0	1.7	1.6
Eriogonum umbellatum	1.7	2.1	4.3	4.1	3.6 +	1.3
Fragaria virginiana	0	0	0	0	2.5	5.7
Galium boreale	0	0	0	0	.2	0
Geranium viscosissimum	8.7	12.6	5.7 +	3.7	8.0	9.5
Geum triflorum	2.0	5.3	5.2	9.6	2.5	2.9
Helianthella uniflora	.2	.6	2.6	7.7	0	0
Hieracium sp.	0	0	0	0	.5 *	.1
Linum perenne	0	0	.2	.2	.6	1.1
Lupinus argenteus	1.3 +	0	1.2	0	2.2	.8
Perideridia gairdneri	3.4 +	.2	2.3	0	4.4 *	.6
Phlox multiflora	0	0	.4	1.5	0	0
Polygonum douglasii	14.9	.5	.3	.1	4.9 *	1.2
Potentilla arguta	2.2 +	5.3	3.5	2.3	2.8	2.5
Potentilla gracilis	6.2 *	20.1	2.6	3.1	11.9 *	17.7
Senecio integerrimus	0	.1	.2	0	.4	.9
Silene oregana	.2	0	.1	0	.2	0
Smilacina stellata	0	0	0	0	.1	.2
Total forbs	56.0	53.6	43.4	40.2	61.3	53.0
Shrubs						
Artemisia tridentata	0	0	18.3	17.1	0	0

[1]Amounts less than 0.1 but greater than 0.0 are shown as 0.1 percent composition.
[2]Significance of composition differences between years: + = >0.90; * = >0.95.

Table 3—Comparison of frequency data between 1969 and 1988 on three grassland sites on Cliff Lake Bench Research Natural Area (based on 48 permanent plots, each 0.49 m² in size)

	North Grassland		South Grassland		East Pocket	
	1969	1988	1969	1988	1969	1988
	Percent					
Grasses						
Agropyron spicatum	0	0	17	6	0	0
Agropyron subsecundum	54	52	58 +[1]	38	79	62
Bromus anomalus	33	27	69 **	31	48 *	25
Bromus carinatus	75	75	19	19	38	44
Calamagrostis rubescens	33	21	0	0	35 **	0
Danthonia intermedia	27	19	50	54	67	69
Deschampsia cespitosa	4	0	0	0	8	0
Festuca idahoensis	88	88	98	88	98 *	79
Koeleria cristata	42	54	31 *	12	17 **	44
Melica spectabilis	44 **	15	0	2	65 **	10
Poa ampla	8	17	21	21	4 *	23
Poa interior	23 +	44	0	2	6	17
Poa sp.	0	0	4	6	6	2
Stipa occidentalis	29	15	75	71	42	42
Stipa richardsoni	0	0	8	2	21	33

(con.)

Table 3—(Con.)

	North Grassland		South Grassland		East Pocket	
	1969	1988	1969	1988	1969	1988
	Percent					
Sedges						
Carex douglasii	0	0	2 *	21	0	0
Carex geyeri	2	0	0	0	10	8
Carex hoodii	0	0	2	4	10 +	0
Carex petasata	6	4	15	19	17	31
Carex raynoldsii	19	25	10	2	0	0
Forbs						
Achillea millefolium	67	67	79	62	90 *	69
Agoseris glauca	48 **	0	40 **	2	19 **	0
Antennaria anaphaloides	0	0	12	8	0	2
Antennaria rosea	6	2	6	4	15 +	2
Arabis spp.	6	0	8	0	2	0
Arenaria congesta	15	6	69 **	27	42 *	21
Aster campestris	38	35	46	29	44	35
Aster integrifolius	27	29	25	25	31	35
Astragalus miser	0	0	12 *	0	2	0
Balsamorhiza sagittata	0	0	8	4	2	0
Campanula rotundifolia	38 **	0	40 **	0	54 **	0
Cerastium beeringiranum	21	19	4	15	0	0
Cirsium vulgare	0	0	4	2	2	0
Clematis hirsutissima	12	17	31 *	10	10	10
Collomia linearis	71	54	31 **	6	56 **	27
Epilobium angustifolium	0	0	0	0	19	2
Erigeron speciosus	6	2	0	0	6	4
Erigeron subtrinervis	42	29	19 **	0	33	35
Eriogonum umbellatum	38	33	62	62	52 **	25
Fragaria virginiana	0	0	0	0	19 *	40
Geranium viscosissimum	90	77	62	52	96 *	79
Geum triflorum	27 +	48	54	62	44	48
Helianthella uniflora	2	2	23	33	0	0
Hieracium sp.	0	0	0	0	19 *	2
Linum perenne	0	0	2	4	27	31
Lupinus argenteus	46 **	0	35 **	0	40 **	8
Perideridia gairdneri	52 **	4	31 **	0	73 **	10
Phlox multiflora	0	0	25	40	0	0
Polygonum douglasii	79 **	25	17 +	4	50	40
Potentilla arguta	35	54	65 *	40	54	50
Potentilla gracilis	56 *	81	40 *	62	90	94
Senecio integerrimus	0	0	6	0	2	2
Silene oregana	4	0	4	0	10 +	0
Smilacina stellata	0	0	0	0	2	2
Shrubs						
Artemisia tridentata	0	0	40	40	0	0

[1]Significance of frequency differences between years: + = >0.90; * = >0.95; ** = >0.99.

perennial forbs as measured by production were, with minor exceptions, those with the highest frequencies. Forbs on the South Grassland did not follow this pattern.

Thus, on these mountain grasslands, perennial species dominance expressed by air-dry production corresponded fairly well with that expressed by frequency. This correspondence appeared to be better for grasses than for forbs. Such correspondence cannot be assumed. These analytical measures are dependent on substantially different plant growth characteristics. Frequency measures are enhanced by rhizomatous growth forms and are not appreciably influenced by size of individuals; production depends on the size of individuals as well as distribution.

The relative merits of production versus frequency data in detecting vegetation change are indicated by comparing the results of the tests of significance of differences between the two years (tables 1 and 3). Of a total of 79 possible opportunities for agreement of species showing significant change (P = >0.95), the two measures agreed on the significance and direction of change two-thirds of the time (52 cases). In 14 cases, a species showed significant change on production plots, but not on the frequency plots. In 13 cases, a species showed significant change on the frequency plots, but not on the production plots.

Environmental Conditions

The environmental conditions before and at the time of sampling vegetation can have a pronounced effect on results. As I have shown previously (Mueggler 1983), vegetation production on mountain grasslands in southwestern Montana can differ as much as 200 percent because of yearly weather differences. Therefore, information on plant growth conditions before sampling is essential to interpretation of measured vegetation differences.

Precipitation and temperature records (table 4) for the National Oceanic and Atmospheric Administration climatological station (Hebgen Dam) closest to the natural area indicate that the weather before the 1988 inventory was very different from that before the 1969 inventory. The 1969 inventory was preceded by at least two relatively wet years. In contrast, the 1988 inventory (the year Yellowstone burned) was preceded by two very dry years. Precipitation during the 1967-68 water year and the 1968-69 wateryear through July was 25 percent and 15 percent, respectively, **above** the 70-year average. Precipitation during the 1986-87 water year and the 1987-88 water year through July was 33 percent and 43 percent, respectively, **below** the long-term average. Mean May through July temperatures before to the 1969 inventory were within 1 °F of normal, whereas in 1987 and 1988 they were 2.5 °F and 5.1 °F above the long-term average, respectively.

The relatively dry conditions during the 1988 inventory made species recognition and productivity estimates difficult. In early August of 1969, the percent dry matter of the graminoids generally ranged between 35 and 60 percent, while in early August 1988 it ranged between 65 and 75 percent. Similarly, in 1969 the dry matter of forbs generally ranged between 24 and 55 percent, while in 1988 it ranged between 55 and 90 percent. Many of the early ephemeral species were probably missed in both 1969 and 1988 because they dried and disintegrated before the inventories. However, other

Table 4—Precipitation and average temperature records[1] for the two water years preceding the 1969 and 1988 inventories (Hebgen Dam, MT data[2])

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
						Precipitation (inches)							
Long-term Ave.	1.69	2.40	3.30	3.47	2.54	2.48	1.95	2.81	3.31	1.58	1.99	1.85	29.37
1967-68	3.57	2.40	5.53	3.85	2.77	1.28	.99	3.05	3.94	.79	6.28	2.31	36.76
1968-69	1.30	4.22	3.23	6.90	3.91	.52	1.21	2.11	3.79	2.15	.54	1.54	31.42
1986-87	.63	1.73	.36	2.17	1.17	.89	.11	2.79	1.86	4.83	2.57	.19	19.30
1987-88	.02	1.92	2.40	2.06	1.66	1.58	1.29	1.74	.79	1.20	.21	.54	15.41
						Average temperature (°F)							
Long-term Ave.	40.1	25.3	14.4	11.6	16.7	22.0	33.4	44.8	53.1	60.9	59.2	50.7	
1967-68	40.1	26.2	8.8	9.4	20.6	27.5	30.9	43.1	52.9	61.9	55.3	49.0	
1968-69	40.3	24.0	13.4	16.2	16.8	18.0	38.1	49.4	51.4	59.9	62.1	53.6	
1986-87	42.1	25.4	10.6	10.0	16.4	28.1	41.7	50.3	56.8	59.1	57.6	54.8	
1987-88	42.7	28.6	16.0	10.1	16.8	23.3	37.6	48.7	60.5	64.8	62.6	52.0	

[1]U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, climatological data.

[2]Hebgen Dam is about 15 miles northeast of and 500 ft lower than Cliff Lake Bench; long-term averages are based on about 70 years of records.

perennial species such as *A. glauca* and *P. gairdneri* that were relatively common in 1969 were seldom seen in 1988. The abundance of annual forbs also appeared to be greatly reduced by the 1988 drought.

The relative abundance of grasshoppers also had an uncertain effect on the comparative results of the vegetation inventories. Although present in 1969, grasshoppers were not sufficiently abundant to warrant concern. Grasshoppers were extremely abundant in 1988, however, averaging an estimated 10 to 20 per square meter at the time of inventory. (The rider on the cattle allotment adjacent to the natural area indicated he had not previously seen such a great abundance of grasshoppers on Cliff Lake Bench. He expressed concern that the cattle would need to be moved out early because of the forage used by the grasshoppers.) Apparently, grasshoppers were equally abundant in early August of 1960, judging from notes prepared by J. E. Schmautz in the Natural Area files. Although apparently not common, such extreme population cycles obviously reoccur. The grasshoppers preferred some plant species over others. *L. argenteus* appeared to be particularly favored (this was also noted by Schmautz). *Lupinus*, when seen at all, was invariably stripped of its leaves and flowers with only a spindly, ill-defined stem remaining. Considerable amounts of *Lupinus* were present in 1969, but very little was seen in 1988. How much of this difference can be attributed to the grasshoppers is uncertain. Undoubtedly, the outbreak of grasshoppers also affected the relative abundance of other plant species.

EFFECTS OF PLOT SIZE ON FREQUENCY

Frequency of occurrence of individual species on five different-sized plots was determined for the North Grassland (table 5) and the South Grassland (table 6) in 1988. Note that the 0.49-m^2 plots were the 48 plots used to determine plant production. Although located on the same immediate area, they were not part of the nested-plot series. Plots from 0.25 m^2 through 0.0025 m^2 were nested; 150 of each were used to sample a grassland. Thus, plot area examined on a grassland was 23.53 m^2 for the 0.49-m^2 plot, 37.5 m^2 for the 0.25-m^2 plot, to just 0.38 m^2 for the smallest plot.

Since species were not completely enumerated on the grasslands, the number of species missed by each size of frequency plot is unknown. However, plot sizes less than 0.25 m^2 sampled conspicuously fewer species. An apparent exception was the species missed by the 48 0.49-m^2 plots on the North Grassland, which actually encompassed less than two-thirds of the area sampled by the 150 0.25-m^2 plots. Even the most abundant species did not exceed 90 percent frequency on the largest plots used.

It appears that on these grasslands 0.5-m^2 plots are about the maximum size for sampling frequency of the most abundant species; 0.25-m^2 plots would allow somewhat greater latitude for detecting increases of the abundant species. Plots less than 0.25-m^2 in size do not appear effective for obtaining a meaningful measure of frequency on these areas. The greater the number of plots of a desirable size, the greater the total plot area examined, enhancing the possibility of obtaining meaningful frequency data on scarce species.

PROBLEMS IN OBTAINING RELIABLE DATA

The basic problem in interpreting vegetation data collected to determine the effects of climate change is separating differences caused by temporary influences from those attributable to long-term influences. The temporary influences that I recognized as confounding interpretation of long-term change on these natural grasslands and shrublands were yearly weather differences (growth year) and an insect outbreak (animal influences).

Effects of Growth Year

Vegetation production on the mountain grasslands of western Montana can vary greatly between years. Although total production is likely to be between 85 and 90 percent of the long-term mean for two-thirds of the years, 200 percent differences have been observed between "good" and "poor" growth years (Mueggler 1983). Production variation of vegetation classes can be even greater, with variation of individual species greater still. A good year for the production of grasses is not necessarily a good year for the production of forbs, and vice versa. Individual species apparently react differently to subtle differences in weather; thus increased yields of one species often compensate for decreased yield of another, tending to moderate variations in total production. This means "relative" composition by production shouldn't be relied on as a measure of long-term change.

Yearly weather differences also affect timing of the growth of individual plant species. This can impair data accuracy if sampling is confined to a single visit at the estimated time of maximum production, as is often the case. Early ephemeral species such as *Dodecatheon conjugens*, *Delphinium bicolor*, *Lomatium cous*, and *Fritillaria pudica*, fairly common on similar grasslands (Mueggler 1983), are usually missed when sampling is confined to the single period of maximum vegetation growth. They complete

Table 5—Comparison of species frequencies determined from five different-sized quadrats on the North Grassland: 70 by 70 cm (0.49 m^2), 50 by 50 cm (0.25 m^2), 50 by 25 cm (0.125 m^2), 25 by 25 cm (0.062 m^2), and 5 by 5 cm (0.0025 m^2). Frequencies are based on 150 samples of each plot size except for the 0.49-m^2 size that had 48 samples

	Plot size				
Species	**0.49 m^2**	**0.25 m^2**	**0.125 m^2**	**0.062 m^2**	**0.0025 m^2**
	Percent				
Graminoids:					
Agropyron subsecundum	[1]52	63	42	30	3
Bromus anomalus	27	23	19	13	1
Bromus marginatus	75	69	59	47	11
Calamagrostis rubescens	21	24	20	16	5
Carex douglasii	0	7	5	3	1
Carex petasata	4	2	0	0	0
Carex raynoldsii	25	13	6	5	1
Danthonia intermedia	19	10	7	4	0
Festuca idahoensis	88	81	75	64	13
Koeleria cristata	54	38	25	11	0
Melica spectabilis	15	9	3	1	0
Poa ampla	17	11	6	2	0
Poa interior	44	38	30	21	1
Stipa occidentalis	15	17	13	7	1
Forbs:					
Achillea millefolium	67	57	41	27	1
Antennaria anaphaloides	0	3	2	1	0
Antennaria rosea	2	1	1	1	0
Arenaria congesta	6	6	3	3	0
Aster campestris	35	21	13	5	1
Aster integrifolius	29	21	19	17	1
Campanula rotundifolia	0	1	0	0	0
Cerastium beeringianum	19	17	11	7	2
Chenopodium album	0	1	1	1	0
Clematis hirsutissima	17	5	1	0	0
Collomia linearis	54	30	20	17	3
Erigeron subtrinervis	29	11	5	3	1
Eriogonum umbellatum	33	19	13	7	3
Geranium viscosissimum	77	69	49	31	3
Geum triflorum	48	23	14	7	1
Helianthella uniflora	2	5	5	5	1
Hieracium sp.	0	1	1	0	0
Lupinus argenteus	0	1	1	1	0
Perideridia gairdneri	4	0	0	0	0
Polygonum douglasii	25	19	12	8	1
Potentilla arguta	54	36	25	16	2
Potentilla gracilis	81	75	64	49	8

[1]The 0.49-m^2 plots are not part of the "nested" plot series, although they are on the the same immediate area. Their frequency can be greater or smaller than the other plots, whereas the frequency of the largest nested plots can only be greater or the same as that of the smaller plots in the nested plot series.

Table 6—Comparison of species frequencies determined from five different-sized quadrats on the South Grassland: 70 by 70 cm (0.49 m^2), 50 by 50 cm (0.25 m^2), 50 by 25 cm (0.125 m^2), 25 by 25 cm (0.062 m^2), and 5 by 5 cm (0.0025 m^2). Frequencies are based on 150 samples of each plot size except for the 0.49-m^2 size that had 48 samples

Species	Plot size				
	0.49 m^2	**0.25 m^2**	**0.125 m^2**	**0.062 m^2**	**0.0025 m^2**
	Percent				
Graminoids:					
Agropyron spicatum	[1]6	3	1	0	0
Agropyron subsecundum	38	43	30	16	4
Bromus anomalus	31	9	4	2	0
Bromus marginatus	19	29	21	13	5
Carex douglasii	21	3	2	1	0
Carex hoodii	4	3	2	1	0
Carex petasata	19	12	8	5	0
Carex raynoldsii	2	0	0	0	0
Danthonia intermedia	54	49	41	29	5
Festuca idahoensis	88	73	67	55	12
Koeleria cristata	12	11	7	4	0
Melica spectabilis	2	0	0	0	0
Poa ampla	21	27	19	12	0
Poa interior	2	2	0	0	0
Stipa occidentalis	71	62	49	34	5
Stipa richardsoni	2	18	15	13	3
Forbs:					
Achillea millefolium	62	53	43	30	2
Antennaria anaphaloides	8	9	4	1	0
Antennaria rosea	4	0	0	0	0
Arenaria congesta	27	5	5	4	0
Aster campestris	29	41	31	24	0
Aster integrifolius	25	26	24	21	3
Campanula rotundifolia	4	2	1	0	0
Cerastium beeringianum	15	17	13	7	0
Circium vulgare	2	3	2	1	0
Clematis hirsutissima	10	3	1	0	0
Collomia linearis	6	0	0	0	0
Erigeron subtrinervis	0	3	2	1	0
Eriogonum umbellatum	62	46	31	21	5
Geranium viscosissimum	52	40	21	11	0
Geum triflorum	62	53	47	37	4
Helianthella uniflora	33	23	15	6	0
Linum perenne	4	3	0	0	0
Phlox multiflora	40	27	20	13	1
Polygonum douglasii	4	7	5	3	0
Potentilla arguta	40	24	11	5	0
Potentilla gracilis	62	47	34	23	2
Shrubs:					
Artemisia tridentata	40	15	8	5	1

[1]The 0.49-m^2 plots are not part of the "nested" plot series, although they are on the the same immediate area. Their frequency can be greater or smaller than the other plots, whereas the frequency of the largest nested plots can only be greater or the same as that of the smaller plots in the nested plot series.

their growth early in the season and dry. Their dried growth shatters, becoming unrecognizable by the time of sampling. Other later-developing species may mature and dry early and becoming unrecognizable in poor growth years, even though they would still be recognizable in good years.

Such is believed to be the case with *A. glauca, P. gairdneri*, and *C. rotundifolia* on the Cliff Lake Bench grasslands. The 1969 to 1988 frequency comparisons indicated these perennial species decreased significantly. However, I visited the natural area in late summer of 1991 (a reasonably good growth year) and checked the frequencies of these three species. Although the 1969 and 1988 inventories indicated a frequency decrease for *A. glauca* of from 48 to 0 percent, 40 to 2 percent, and 19 to 0 percent on the North Grassland, South Grassland, and East Pocket respectively, 1991 frequencies on the same plots were 40 percent, 9 percent, and 29 percent respectively, even when observed in September about a month after the period of maximum growth. The 1969 to 1988 frequencies of *P. gairdneri* decreased from 52 to 4 percent, 31 to 0 percent, and 73 to 10 percent on the three grasslands. In 1991 its frequency was 58 percent, 16 percent, and 15 percent, respectively. The 1969 to 1988 frequencies of *C. rotundifolia* declined from 38 to 0 percent, 40 to 0 percent, and 54 to 0 percent. In 1991 the frequencies were 29 percent, 0 percent, and 60 percent, respectively. Obviously, these species did not undergo the degree of long-term change suggested by the 1969 to 1988 data. Annuals are very opportunistic and vary greatly in abundance and period of active growth, depending on the growth year.

Sampling deficiencies caused by early drying and shattering could be alleviated by periodic sampling during the growing season. However, this is often impractical because time and money are limited, or the site is inaccessible early in the season. The effect of the growing season on plant development should be recognized as a possible source of error in interpreting data on long-term change in community composition.

EFFECTS OF ANIMAL INFLUENCES

Removal of herbage by grazing animals before sampling can have a profound effect on inventory results, particularly with measures of production. Differential use of plant species because of palatability preferences can severely alter species composition based on herbage production. The effects of many years of grazing, especially heavy grazing, can have long-term effects on community composition, severely distorting any long-term changes that might be attributable to climate change. This would be true even if the plants were protected from grazing during the inventory years. For long-term climate change studies, areas permanently protected from livestock grazing, preferably with a history of minimal grazing, are desirable.

Although Cliff Lake Bench has been protected from domestic livestock grazing for over 35 years, and only lightly grazed earlier, deer, elk, and moose frequent the area. Although their use of the herbaceous vegetation has been apparent at times, I have not considered it sufficient to measurably alter community composition on the grasslands. The adjacent aspen (*Populus tremuloides*) groves, however, have been severely affected by game browsing. Aspen reproduction is suppressed by browsing. The trunks of many of the mature trees have been barked, probably by moose, permitting pathogen invasion. This is similar to conditions reported elsewhere with high concentrations of wild ungulates (Krebill 1972).

Population eruptions of smaller animals are largely uncontrollable and can have a major impact on vegetation monitoring. Fortunately, such eruptions are generally short-lived (1 or 2 years). Although eruptions affect monitoring results in outbreak years, they generally do not persist long enough to cause major long-term changes in vegetation composition on grasslands. The extremely high number of grasshoppers on Cliff Lake Bench in 1988 unquestionably influenced inventory results. Grasshoppers chewed on everything from plant material and data sheets, to measuring tapes' leather covers. The distortion of vegetation production data by the unusual dryness of the growth year was compounded by the unknown, but presumably unusually large, amount of herbage consumed by the grasshoppers. Such insect eruptions can also affect frequency data, as demonstrated by the 1988 data on Cliff Lake Bench. *Lupinus argenteus* was particularly favored by the grasshoppers, as evidenced by the few remaining identifiable stems stripped of leaves. In 1969, the frequencies of *L. argenteus* on the North Grassland and East Pocket were 46 and 40 percent, respectively. In 1988, the frequencies were reduced to 0 and 8 percent, respectively. In 1991 they had rebounded to 6 and 21 percent. *Lupinus argenteus* usually does not dry until late in the growing season, so it is unlikely that it was missed because of the dry year. It was most likely missed because grasshoppers ate it.

On shrublands, population eruptions of small mammals such as voles (*Microtus* spp.) can also seriously affect vegetation composition, especially that of the shrub component. In the winter of 1963-64, population explosions of voles on local areas in southwestern Montana caused up to 80 percent mortality of *A. tridentata* plants on sagebrush-grass steppe areas similar to the South Grassland (Mueggler 1967). This shrub damage would be

reflected in the vegetation composition data for many years afterward. Such uncontrollable animal impacts must be accounted for when interpreting data collected to monitor long-term climate change.

CONSIDERATIONS

The experience on the Cliff Lake Bench Research Natural Area exemplifies the types of problems that can be encountered in monitoring long-term vegetation change in natural ecosystems. Although most human-caused perturbations such as livestock grazing or logging can be avoided on the site, the effect of natural variations and disturbances must be accounted for, either in monitoring design or in interpretation of results.

Yearly monitoring would track short-term natural variability in vegetation composition, permitting long-term trends in species change to be detected. However, yearly monitoring is costly and seldom feasible. Monitoring at several-year intervals is more realistic, but provides less information to help separate short-term variability from long-term change. Sampling techniques that are relatively insensitive to natural yearly variation are preferred. Measures of species frequency appear superior to measures of species production in this regard. Although frequency is not an "absolute" measure, it does appear to be a reliable indicator of change in the abundance of a species. Frequency appears especially appropriate for detecting change in minor species.

The meaningfulness of frequency measures is highly dependent on plot size and the number of plots used. Nested plots with a range of sizes are commonly used to accommodate species with widely different abundance. However, on mountain grasslands such as these, a 0.25-m^2 plot appeared optimum for obtaining meaningful data on most, if not all, species. An investigator's effort might be better used to sample a greater number of plots rather than sampling different size plots. Of course, it is essential to be consistent in using the same size of plots, and preferably the same number of plots, in subsequent monitoring.

Change in all plant species cannot be monitored by a single yearly measurement. Early ephemeral species are inevitably missed if sampling is timed to accommodate development of the majority of species. Either the early developing (and drying) species are missed, or the area must be sampled at least twice during the growing season, timing the sampling to accommodate different major plant development strategies.

The peculiarities of a given sampling year can have a substantial effect on the resulting data, even when the appropriate sampling techniques are selected. The investigator must be sensitive to "unusual" phenomena that may temporarily distort the results. The extreme drought combined with an infestation of grasshoppers during 1988 on Cliff Lake Bench is an example of such temporary distortion on the grassland areas. On the other hand, large wild ungulate browsing has markedly distorted the reproduction dynamics of the adjacent aspen groves on the natural area. Continuation of such wild ungulate influence could have a long-term effect, obscuring changes in the stability of aspen groves caused by climate shift.

REFERENCES

Hironaka, M. 1985. Frequency approaches to monitor rangeland vegetation: Symposium on use of frequency and density for rangeland monitoring. In: Krueger, William C., chairman. Proceedings 38th Annual Meeting, Society for Range Management; 1985 February; Salt Lake City, UT. Denver, CO: Society for Range Management: 84-86.

Keane, R. E.; Jensen, M. E.; Hann, W. J. 1990. ECODATA and ECOPAC: analytical tools for integrated resource management. The Compiler. 8(3): 24-37.

Krebill, R. G. 1972. Mortality of aspen on the Gros Ventre elk winter range. Res. Pap. INT-129. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 16 p.

Mueggler, W. F. 1967. Voles damage big sagebrush in southwestern Montana. Journal of Range Management. 20(2): 88-91.

Mueggler, W. F.; Stewart, W. L. 1980. Grassland and shrubland habitat types of western Montana. Gen. Tech. Rep. INT-66. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 154 p.

Mueggler, Walter F. 1983. Variation in production and seasonal development of mountain grasslands in western Montana. Res. Pap. INT-316. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 16 p.

Mueggler, Walter F. 1992. Cliff Lake Bench Research Natural Area: problems encountered in monitoring vegetation change on mountain grasslands. Res. Pap. INT-454. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 13 p.

Vegetation data collected on mountain grasslands in southwestern Montana in 1969 and again in 1988 serve as an example of problems likely to be encountered in attempting to monitor the effects of climatic change on vegetation. Species production, frequency, and vegetation composition differed significantly, but these were believed to be a result of short-term peculiarities of the sample years, rather than evidence of long-term vegetation change. Ways are suggested to reduce the effects of some of the problems encountered.

KEYWORDS: research natural areas, vegetation monitoring, mountain grasslands, long-term change, environmental impact, climatic change

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

USDA policy prohibits discrimination because of race, color, national origin, sex, age, religion, or handicapping condition. Any person who believes he or she has been discriminated against in any USDA-related activity should immediately contact the Secretary of Agriculture, Washington, DC 20250.

Printed on recycled paper

☆U.S. GOVERNMENT PRINTING OFFICE: 1992-673-041/61002